A New High-Voltage Crowbar

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A crowbar is described which is capable of holding off very high voltage, 80 kV or greater, using two or more mercury-pool ignitrons connected in series. This system will replace a single high-voltage ignitron which has required lengthy processing prior to use and which failed to stand off voltages above 70 kV. It was necessary to perfect a higher voltage device in order to improve the reliability of the crowbar used to protect the high-powered (high voltage) klystron from self-destructive arcs. An experimental version of the crowbar was built and operated. Also an experimental photon generator, using a light-emitting diode and fiber optics and a silicon-controlled rectifier with which to pulse the ignitron, was built and tested. Test results are presented, and the performance has been essentially as predicted. The device will be used on the 400-kW transmitting subsystem.

I. Introduction

The 400-kW transmitter located at GDSCC utilizes a klystron to generate and transmit the necessary RF signals to track and recover telemetry from space vehicles. Due to the high voltage (70 kV) used on the klystron tubes, they may experience internal arcing. This arcing can very easily destroy the klystron. Therefore, it is advisable to protect the tube from these high-voltage arcs by the use of a crowbar. A crowbar is a protective instrument that detects high-voltage arcs in the klystron and short circuits the destructive high currents from the klystron through the crowbar until the high voltage can be removed. A number of different types of crowbars were considered: triggered spark gaps, spark gaps, thyratrons, and mercury pool ignitrons. Most devices could not handle the high current, high voltage, or were too slow, but the chief problem was the high voltage. An earlier version of an ignitron protective device (crowbar) was designed and developed in 1967 using a multigridded ignitron (NL1028). See Ref. 1. These ignitrons were designed to operate at high voltage; however it was found that only a very small percentage of tubes manufactured may be used for high voltage. Their initial cost is very high and the yield is poor; a new tube requires 72 h of processing prior to use. These are the events that led to the development of the new series ignitrons. Therefore, it was decided to place two smaller 50-kV mercury-pool ignitrons in series so as to use their excellent high-current characteristics and their fast response time. The 50-kV unit has been in volume production and has a good record for reliability. This paper will present data to this date and outline future plans.

II. High-Voltage Crowbar System

Figure 1 shows the two mercury-pool ignitrons as they are mounted in their plastic tubing and corona shield, and Fig. 2 shows the electrical schematic as the ignitrons are connected.

In this configuration, the tubes must be triggered on simultaneously; they can be gated on with a balanced pulse transformer or as shown in Fig. 2. The latter technique was chosen because the pulse transformer would have to be insulated for 35 kV and balanced. This would make the transformer very large and cumbersome.

Figure 2 shows the experimental configuration. Each tube (GL37248) has a maximum hold-off voltage of 50 kV. Theoretically, the crowbar system described herein is capable of 100 kV and would be more than adequate for reliable operation in the 400-kW transmitter at 70 kV. The circuit operates in the following manner. If the klystron arcs, the arc is sensed and develops a pulse through a light-emitting diode (diode laser), which will be explained later. This infrared pulse is transmitted through fiber optics to the high-voltage deck and triggers an infrared detector which, in turn, gates a large silicon-controlled rectifier (SCR). The SCR must be capable of being pulsed for 10 μs and must carry 1000 A. This pulse is then applied to the ignitor through a step-up transformer which, in turn, ionizes the mercury in V1. V1 then conducts discharging C1 through R4. The voltage drop across R4 ignites V2 which goes into conduction also. The ignitrons are almost a perfect switch when conducting, the internal resistance being only 1 mΩ. The small power supply in Fig. 2 is connected to the holding anode. This is needed if the current decreases too fast and turns the tube off (squelches the mercury arc). Test results indicate that this does occur at lower voltages, 50 kV or less.

One of the problems existing in the crowbar is that the cathode is floating at -70 kV. This means that isolation must be maintained between the photon generator operating at ground potential and the ignitor firing circuit operating at klystron cathode potential. Figure 3 shows a block diagram of the entire protective system. Isolation is accomplished by generating infrared pulses using a gallium arsenide (GA) laser, transmitting these photons through the light pipe (isolator) and triggering the infrared detector on the high-voltage deck which develops the high-powered pulse to the ignitor and causes the ignitrons to conduct. All of the components are solid state. In many of the components separate tests had to be made in order to decide if they were usable. For instance, published data on the large SCR gave a delay time of 1.5 μs, but it was established that if the gate were pulsed hard, the delay was 200 ns, with no apparent degradation. A very sensitive gate circuit had to be developed in order to use the GA laser as there is a large loss factor (75%) through the fiber optics (light pipe). This uses a sensitive, light-activated SCR which triggered another sensitive SCR. The SCR generated an electrical pulse suitable to fire the laser which propagated a light pulse through the fiber optics, and the light detector responded every time.

This crowbar system has been pulsed many hundreds of times and is performing as expected. The measured response time of 3 μs, using the two tubes in series along with the fiber optics, is more than adequate to protect the klystron. The device has been tested at 80 kV, triggers reliably, and passes the 20,000-A surge current without incident.

Further testing will be done in the future with the holding anode power supply in order to evaluate its effects and at voltages above 80 kV.

Reference

1. Finnegan, E. J., "Klystron Protective Device," in *The Deep Space Network*, Space Programs Summary 37-41, Vol. III, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 30, 1966.

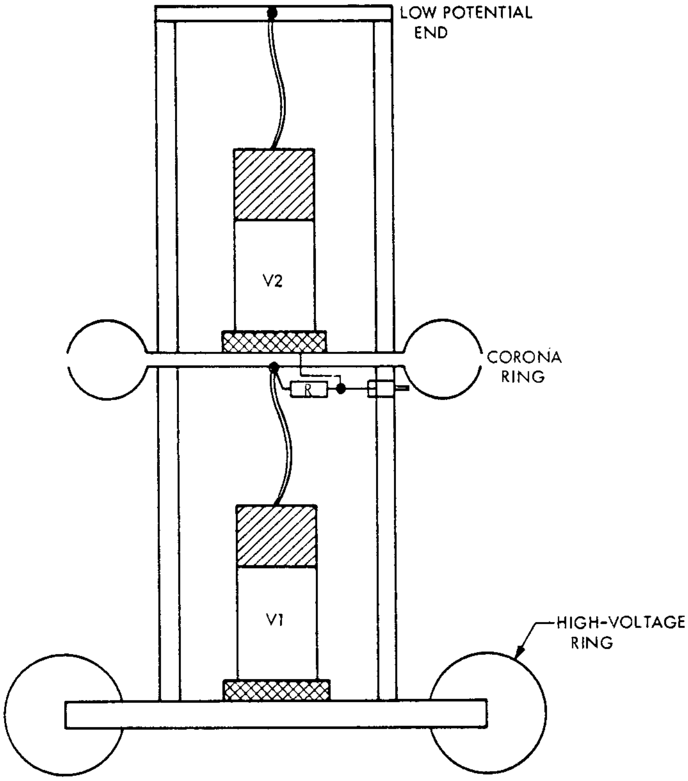

Fig. 1. Series Mercury-pool ignitrons

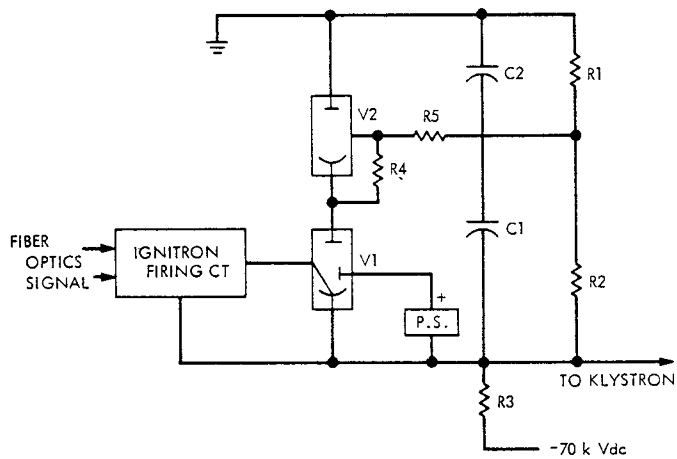

Fig. 2. Experimental configuration, series ignitrons

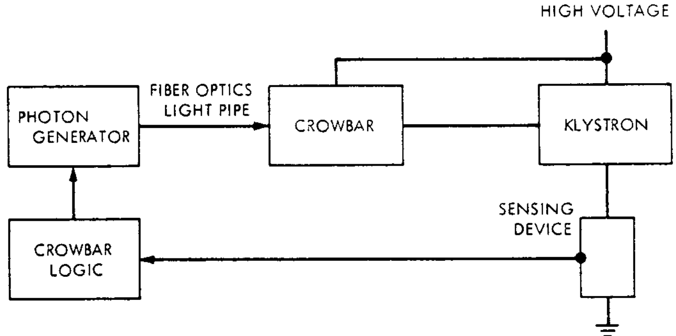

Fig. 3. Crowbar protective system block diagram